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13.4 All-Digital RF Transmitter in 28nm CMOS with Programmable RX-Band Noise Shaping

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The system architecture is depicted in Fig. 1. It is based on direct-conversion programmable duplex distance. This solution enables -160dBc/Hz noise in the digital domain, implementing a fully digital solution to the aforementioned challenge. Instead of requiring DPD or calibration \cite{3-5}, this work presents an RF transmitter that the spectrum of each signal is shaped by the same NTF used in the digital domain. The DMIX block is clocked upconversion to RF carrier fc in the digital domain. The DMIX block is clocked.

The measured output spectrum of a 9MHz CW tone at 900MHz carrier frequency is shown in Fig. 4. At +3dBm output power, the image and LO feedthrough are at -36 and -61 dBc respectively. The CMIM and CMIM are both below -67dBc, barely visible above the noise floor. Fig. 4 also plots the output spectrum with a +0.9dBm LTE20 signal at 850MHz (Band 20), showing excellent E-UTRA ACLR performance of less than -60dBc.

Fig. 5 combines the results of several RX-band noise measurements, performed with modulated LTE carriers at varying duplex distances from the 895MHz TX band. In order to evaluate the effectiveness of all-digital RX-band noise shaping, each measurement was repeated three times: with no MS, with only MS bypassed, and with both MS and MS in use. In the third mode, the averaged RX-band noise is between -155 and -163 dBc/Hz, showing up to 20dB improvement when compared to the first two modes. The results are worst at 45 and 80 MHz duplex distances, due to intermodulation with the fc/16 memory internal clock. The notch center frequency is not restricted to the measured duplex distances, but can be freely tuned within ±447.5MHz of the 895MHz carrier frequency.

Fig. 6 compares the TX performance with previous implementations. This work stands out for its superior linearity and compact die area, while exhibiting state-of-art overall performance. Enabled by the low cost of DSP logic in modern CMOS processes, the TX demonstrates the feasibility of all-digital RX-band noise filtering, requiring only 10-bit DAC to achieve -160dBc/Hz noise without need for DPD, calibration or analog filtering.

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References:


Figure 13.4.1: Block diagram of the transmitter.

Figure 13.4.2: Tree structure encoder used in the mismatch shaping (MS) block.

Figure 13.4.3: Implementation details of the noise shaping sequence generator used in the MS encoder.

Figure 13.4.4: Measured spectra for a 9MHz CW tone at fc=900MHz, and an LTE20 signal at fc=850MHz (Band 20).

Figure 13.4.5: Measurement of RX-band noise at various duplex distances, repeated for different LTE signals and bypass modes.

Figure 13.4.6: Performance summary compared with the state-of-art.
Figure 13.4.7: Die micrograph.